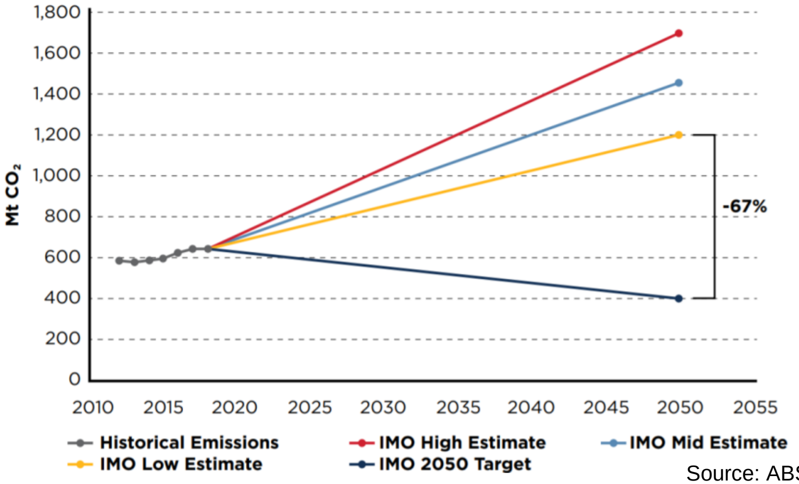
Alternative Marine Fuels Overview

Global Sustainability Center | Mar 3, 2022

Georgios Plevrakis – Vice President of Global Sustainability

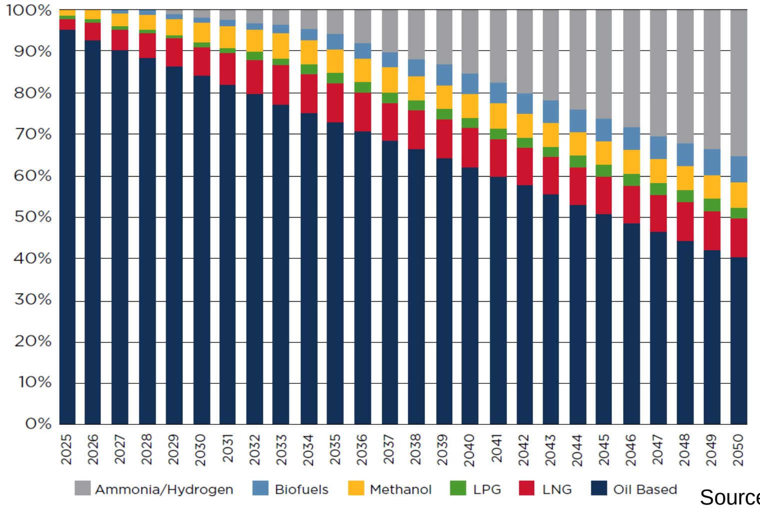
The Decarbonization Challenge

Scenarios of 2050 emissions from shipping



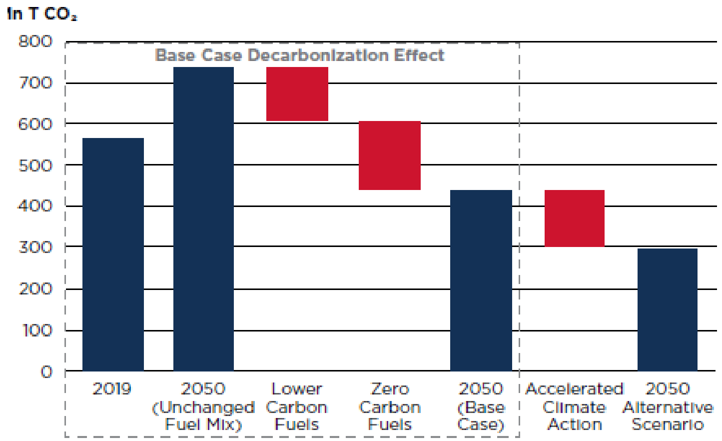
Source: ABS

Forecasted fuel mix in base case scenario



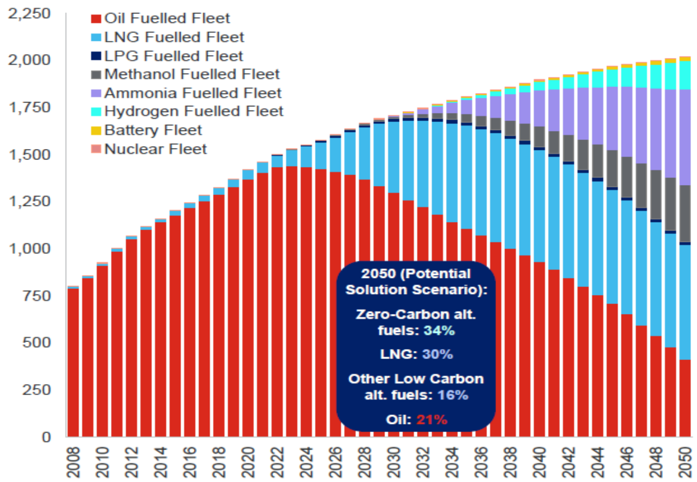
Source: ABS

Forecast of CO_2 Emissions from shipping



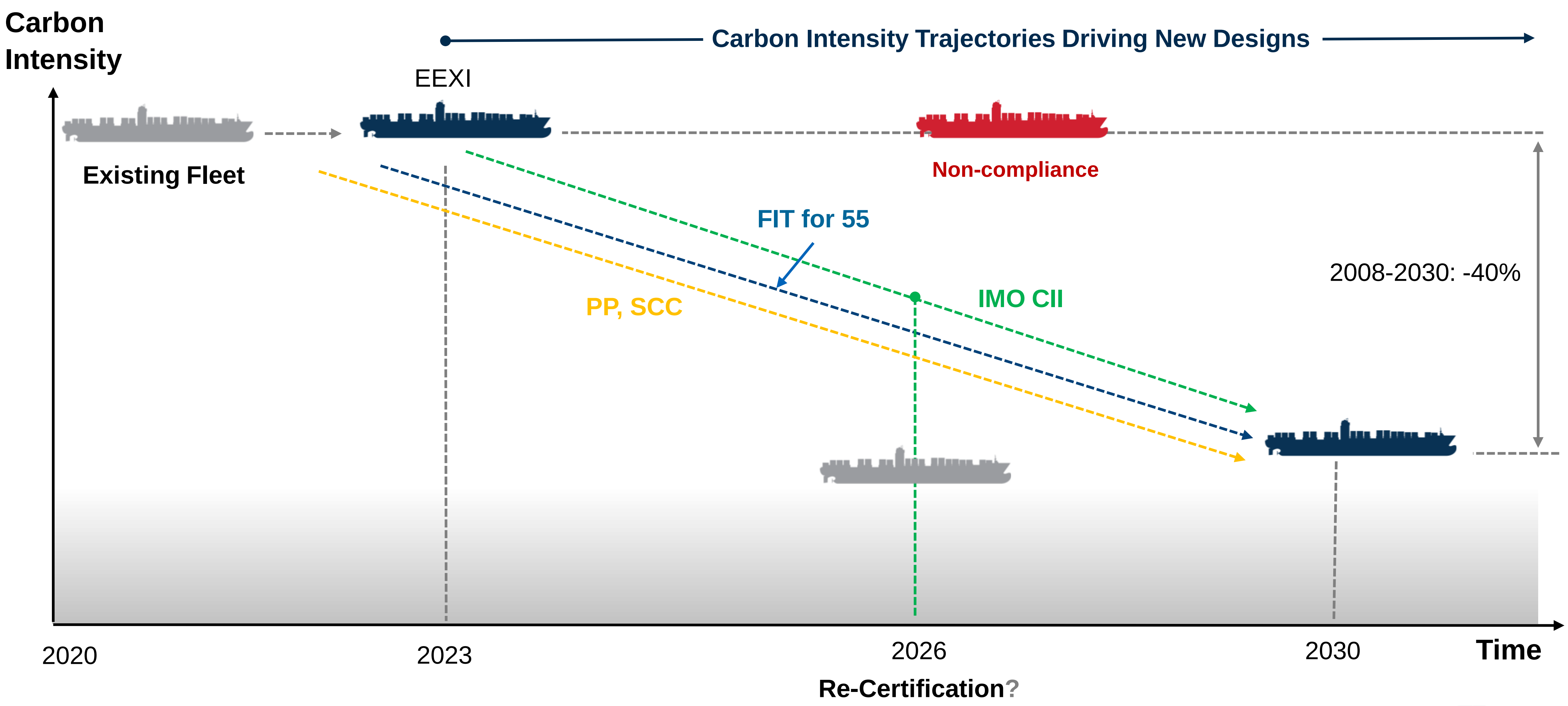
Source: ABS

Potential Solutions Scenario



Source: Clarkson

Emerging Landscape



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COP26 – Shipping Perspective "Net Zero 2050"

CoZEV

9 Cargo Owner Signatories

- Aim to lead this transition by decarbonizing their own maritime freight by 2040, a target well-aligned with a Paris Agreement 1.5°C trajectory
- Call for full decarbonization of the maritime sector by 2050 at the latest
- Ask supply chain partners and policymakers around the world to take swift and ambitious action to bring zero-carbon shipping* solutions to scale

**By zero-carbon fuels, we mean fuels that have zero greenhouse gas emissions on a lifecycle basis, are sufficiently scalable to decarbonize the entire shipping industry, and for which safety and land use concerns have been addressed. Liquified Natural Gas does not meet these criteria*

Clydebank Declaration

22 Signatories

- Facilitate the establishment of partnerships, with participation from ports, operators and others along the **value chain**, to accelerate the decarbonization of the shipping sector and its fuel supply through green shipping corridor projects
- Identify and explore actions to address barriers to the formation of green corridors
- Consider the inclusion of provisions for green corridors in the development or review of National Action Plans
- Work to ensure that wider consideration is taken for environmental impacts and sustainability when pursuing green shipping corridors

Methane Pledge

100 Signatories

- Goal of reducing global methane emissions by at least 30 percent from 2020 levels by 2030 and moving towards using best available inventory methodologies to quantify methane emissions, with a particular focus on high emission sources
- The European Commission is also working to accelerate the uptake of mitigation technologies through the wider deployment of 'carbon farming' in European Union Member States and through their Common Agricultural Policy Strategic Plans, and to promote biomethane production from agricultural waste and residues

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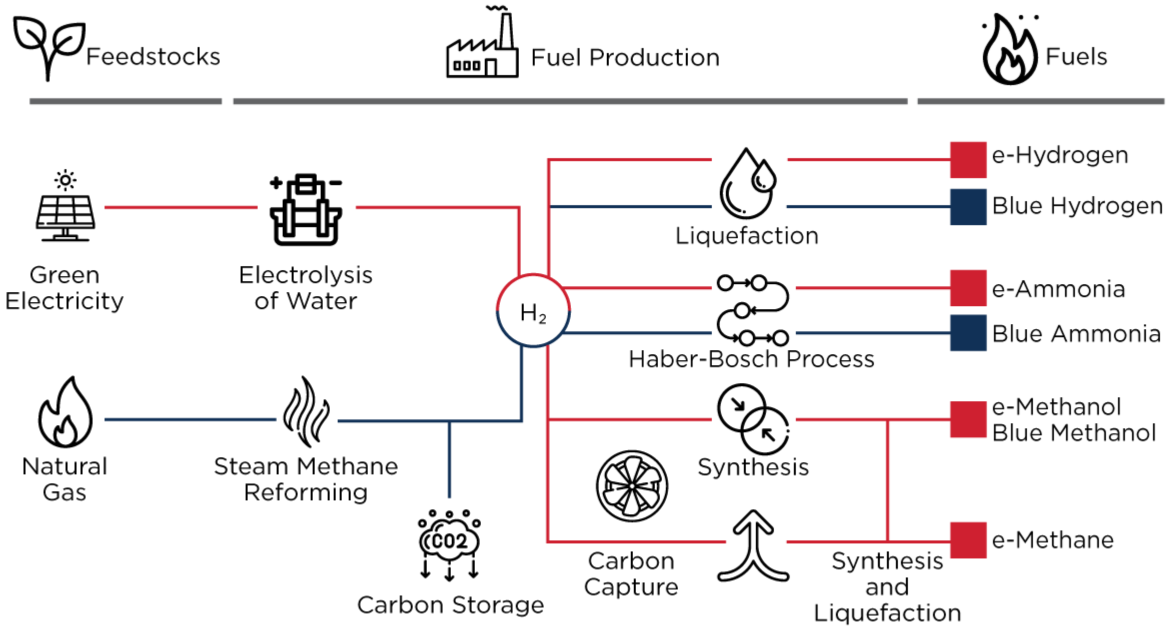
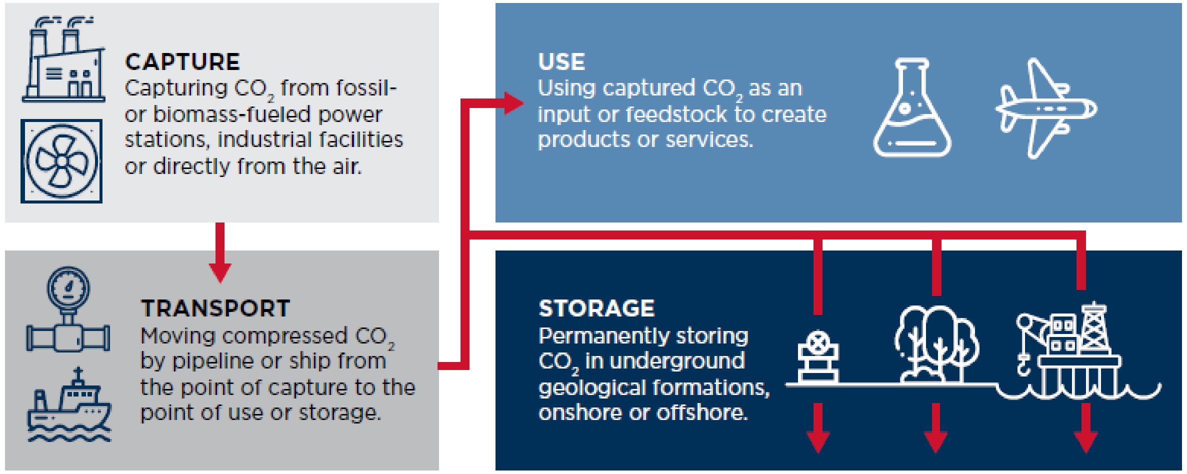
Hydrogen Value Chain – Carbon Value Chain

The value chain includes all activities related to producing Green (and Blue) Hydrogen, conversion of Hydrogen into other fuels/carriers (e.g., Ammonia and E-fuels), transportation and distribution to the final consumers.

Net Zero cannot realistically be delivered without the availability of Carbon Capture, Utilization and Storage (CCUS) technology.

This value chain includes capturing CO_2 at generation points, transporting it, collecting captured CO_2 at hubs, sequestering/storing CO_2 or using it as a feedstock.





Assuming that green fuels can be produced from renewable energy at 60 percent efficiency, the required renewable power production would be 4,582 GW or an amount approximately equal to **seven times** the wind power produced in 2019, and **eight times** the solar power produced that year.

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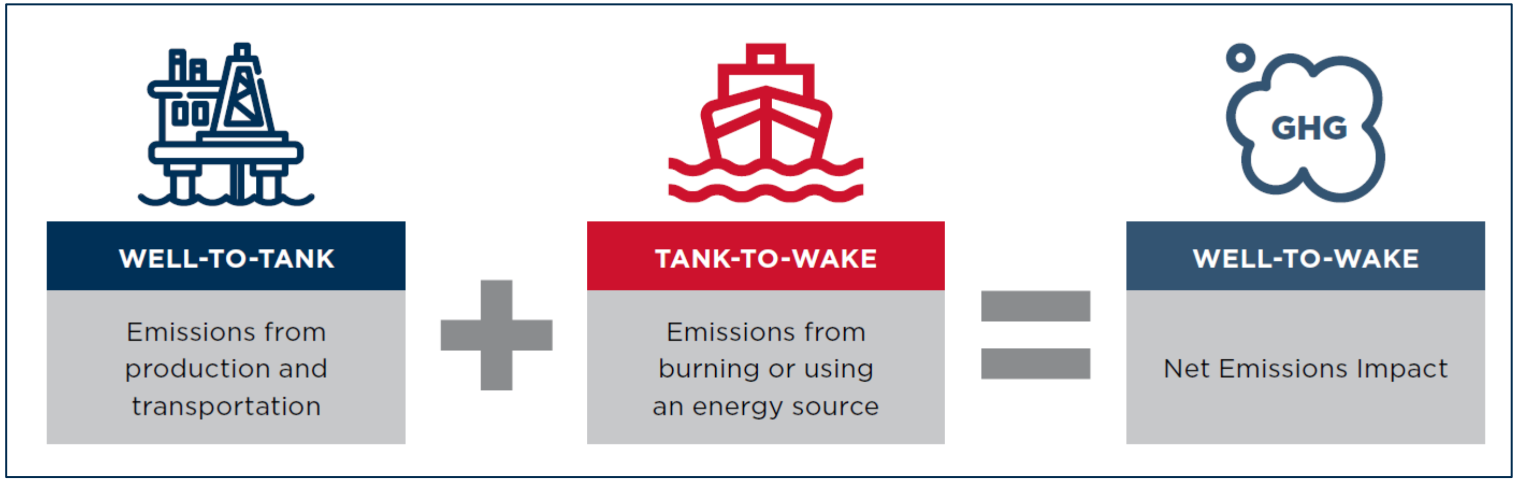
Mid-Term Measures

ISWG-GHG9

- ISWG-GHG 9 report (MEPC 77/WP.6) approved
- **Draft LCA Guidelines**
  - **Well-to-Tank emissions**
    - Categorization of fuels
    - Calculation methodology
  - **Tank-to-Propeller emissions**
    - Emission factors
    - Include methane slip

Life Cycle Analysis (LCA)
Principles; Well-to-Propeller Guidelines



Fit For 55 already has FuelEU frameworks for Well to Wake…

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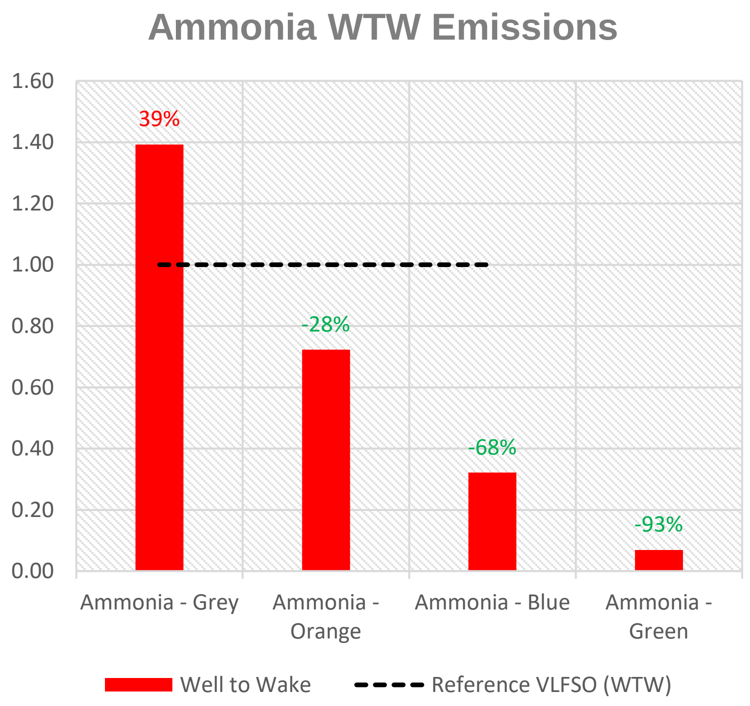
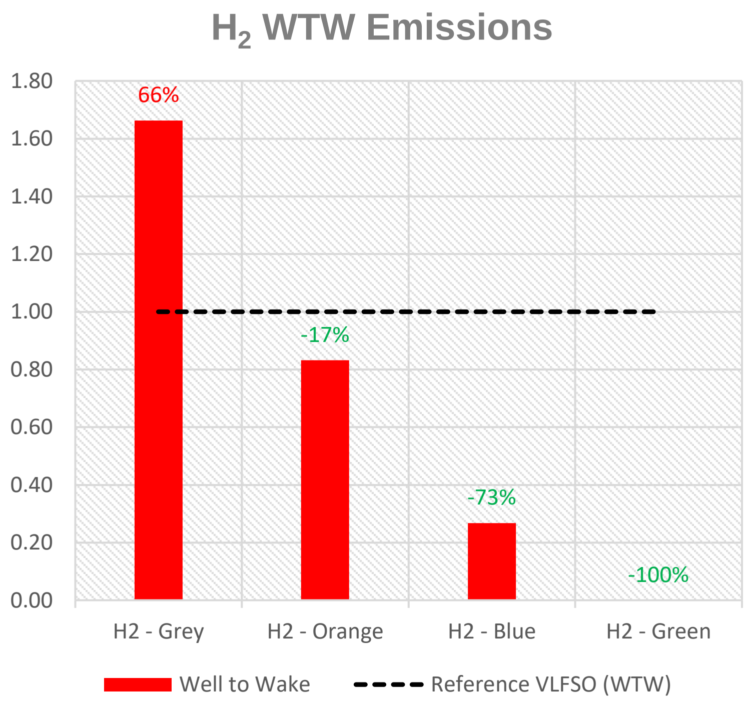
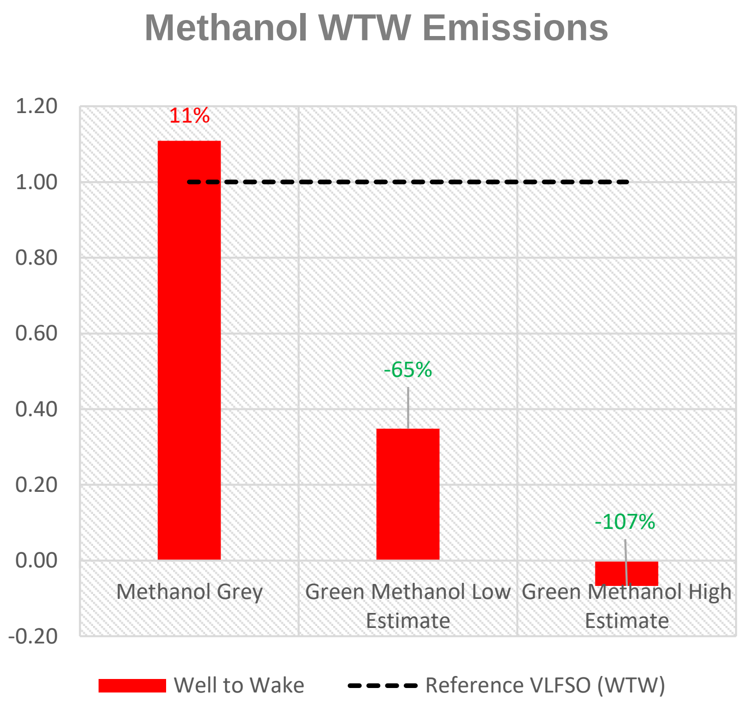
Alternative Fuels Comparison – Emissions



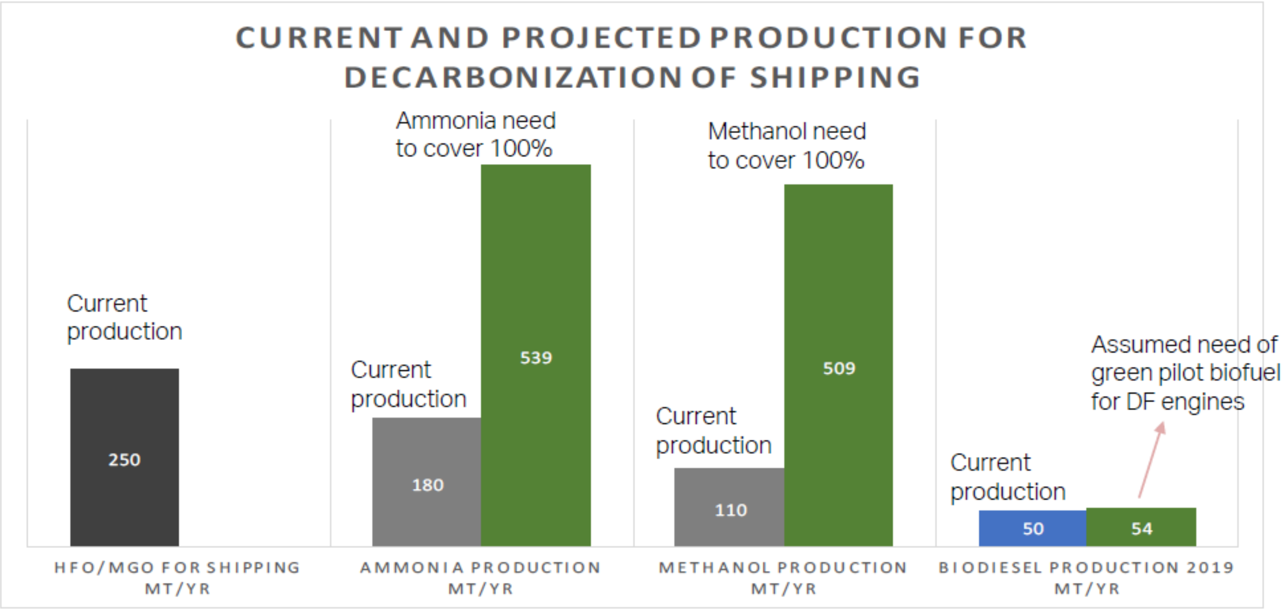


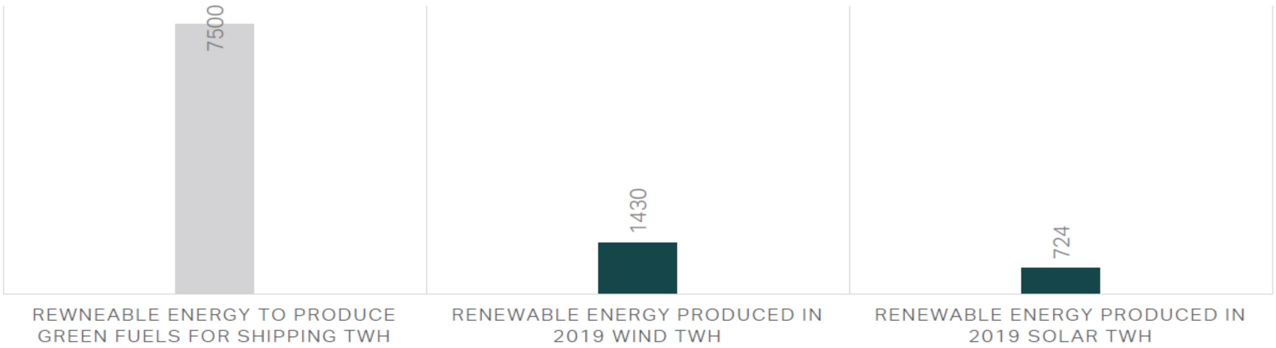


* Numbers from E. Linsdtad, SINTEF

Production Scaling up

- To replace the amounts of HFO/MGO currently used by the shipping sector, a significant increase in production of green fuels will be required.
- If 100% is replaced by green ammonia or green methanol, a 4-5 fold increase in production capacity of those chemicals will be required.
- Growth of shipping sector will also impact increase in fuel used.
- A significant increase of renewable energy is required to produce the green fuels of the future to replace the HFO/MGO for shipping.
- Compared to current worldwide wind/solar energy production a 3-4 time increase is needed, just to cover shipping decarbonization.
- Much more additional renewable energy will be needed for decarbonization of other sectors





Source: Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

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Alternative Fuels Comparison – Characteristics 特性比较

- Common parameters among the four fuels:
  - Can be used in engines at 50% fuel conversion efficiency
  - No sulfur contents
  - NOx Tier II compliance without any aftertreatment

Fuel	Boiling point (ºC)	Safety Risk	Infrastructure	Tank-to-wake CO_2 emissions	Impact on newbuilding ship cost
Hydrogen (H_2, liquid)	-253	High	Nothing available Costly to establish and transport	None	High
Ammonia (NH_3)	-33	Medium	Existing LPG network can be used > 700 LPG carrier	None	Medium
Methanol (CH_3OH)	65	Low	Infrastructure in place available in many ports	less than MGO	Low
Methane (CH_4)	-163	Low	Infrastructure under development, costly to transport	Less than MGO (methane slip not included)	High
Diesel ($C_{16}H_{34}$)	360	Low	Infrastructure in place worldwide	Same as MGO	Low

* Capturing CO2 results in lower production efficiency

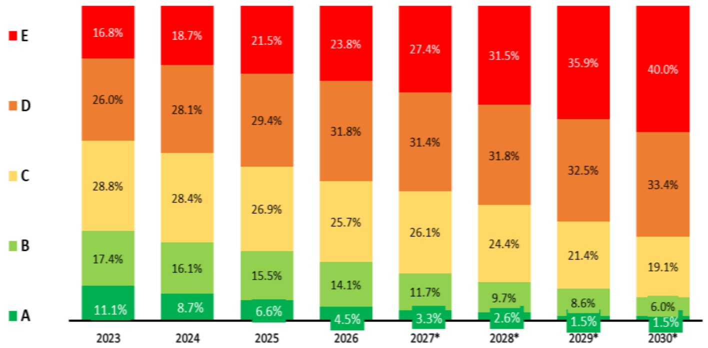
Alternative Fuels Comparison – Storage 存储比较

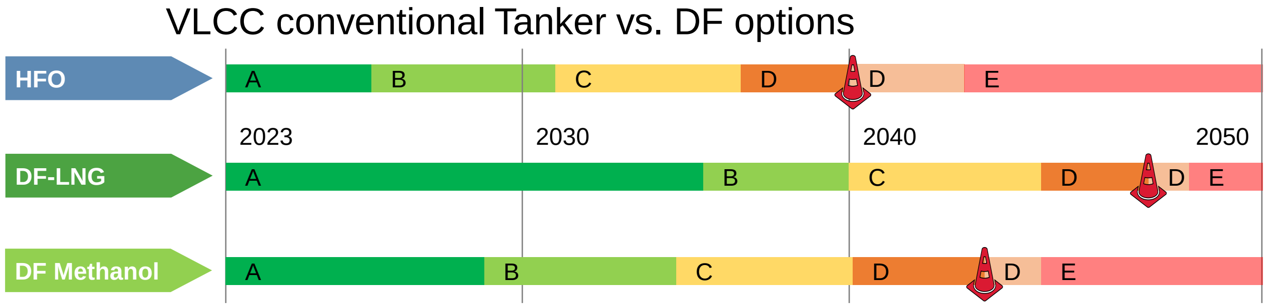
Methanol’s specific energy of 19,700 kJ/kg is much lower than that of LNG and conventional liquid fuels. For the same energy content, methanol requires about 2.4 times more storage volume than conventional fuels.

Properties related to storage				
Energy storage type/chemical structure	Energy content, LHV (MJ/kg)	Energy density (MJ/L)	Fuel tank size relative to MGO	Supply pressure (bar)
Ammonia (NH_3) (liquid, -33°C)	18.6	12.7 (-33°C) 10.6 (45°C)	2.8 (-33°C) 3.4 (45°C)	80
Methanol (CH_3OH) (65°C)	19.9	14.9	2.4	10
LPG (liquid, -42°C)	46.0	26.7	1.3	50
LNG (liquid, -162°C)	50.0	21.2	1.7	300
LEG (liquid, -89°C)	47.5	25.8	1.4	380
MGO	42.7	35.7	1	7-8
Hydrogen (H_2) (liquid, -253°C)	120	8.5	4.2	

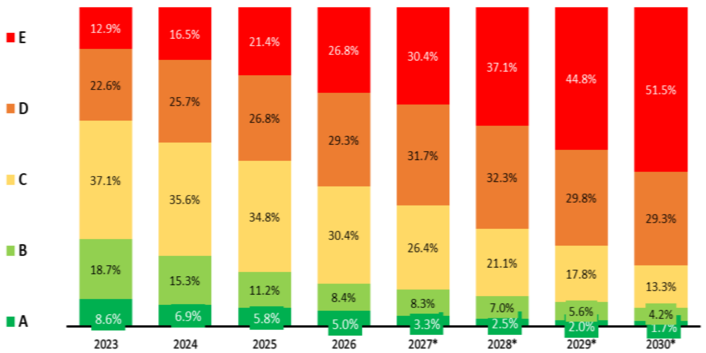
CII Impact

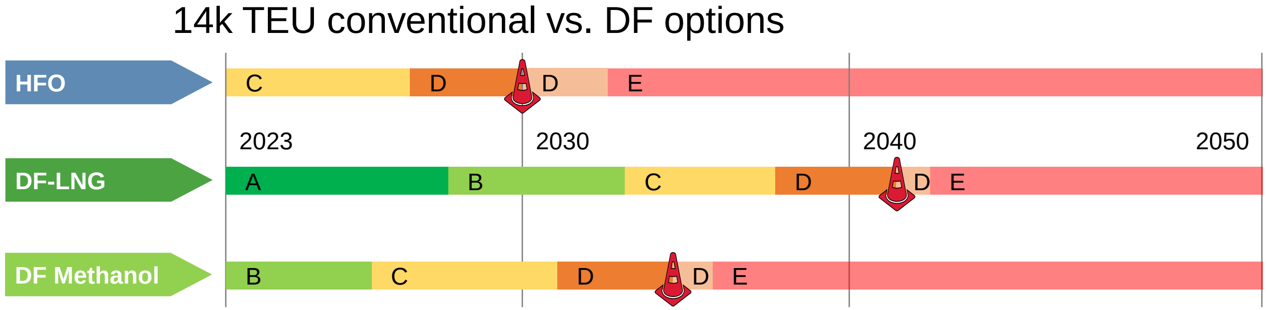
Global
Tanker Fleet



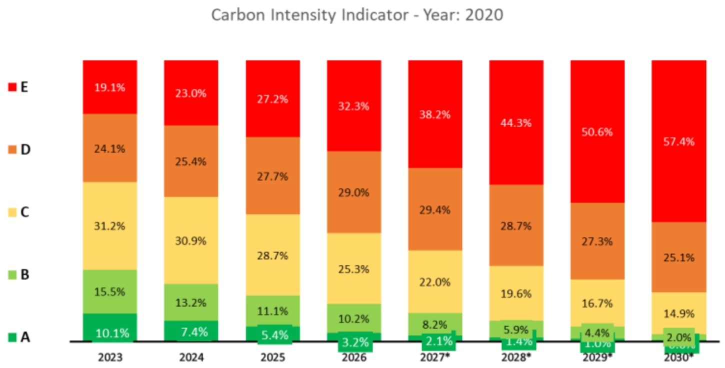


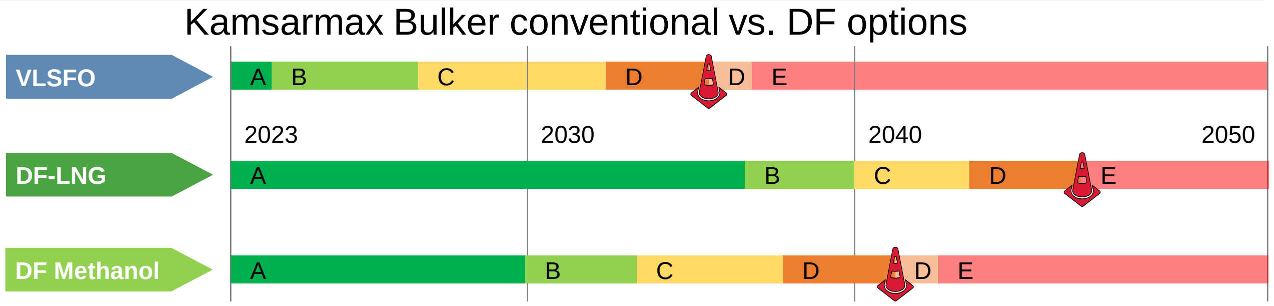
Global
Containership
Fleet





Global Bulk
Carrier Fleet





*The current CII regulation covers until 2030;
the extension to 2050 is based on assumption

Improvement action
required. Additional CAPEX

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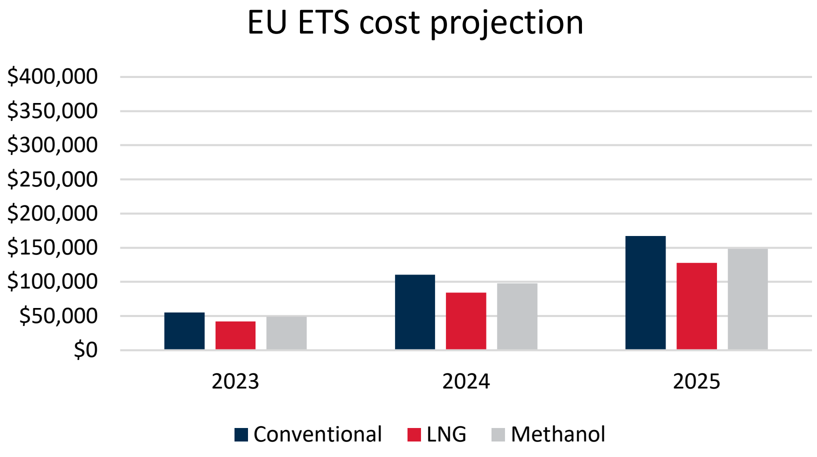
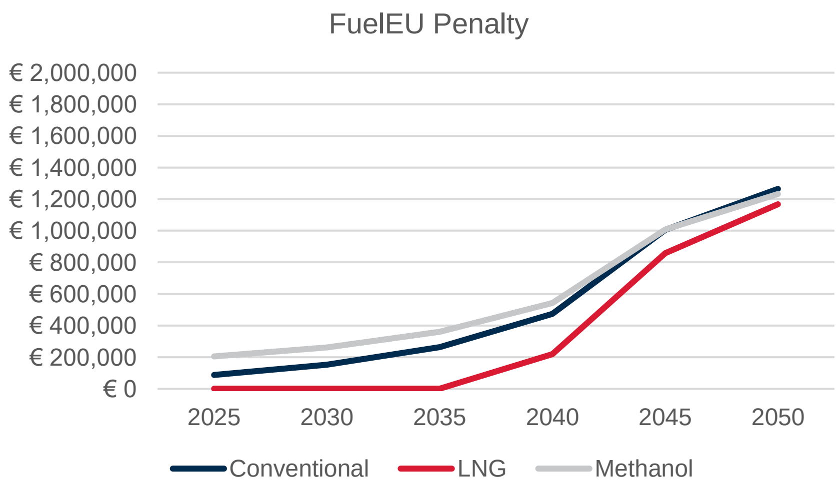
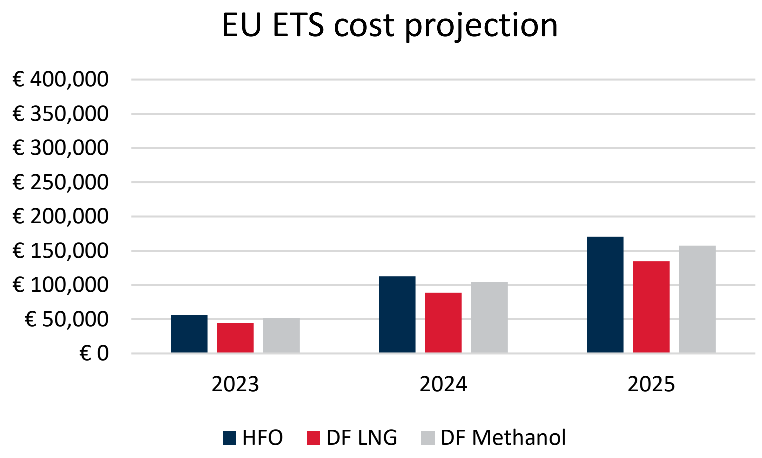
European Measures Impact

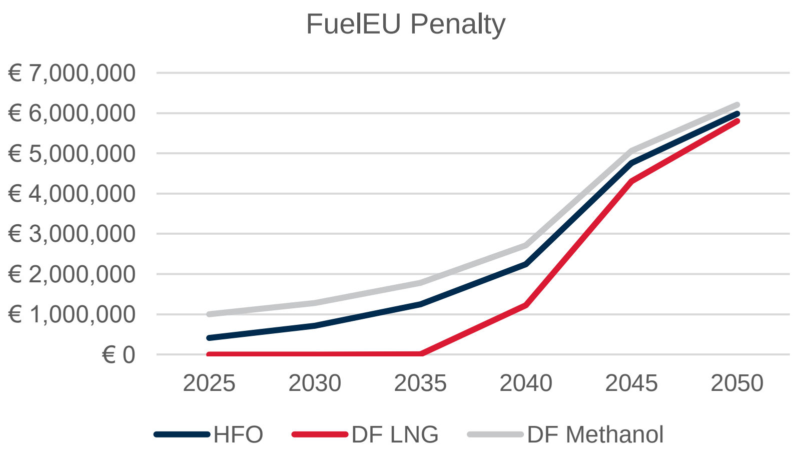
Bulker - Kamsarmax



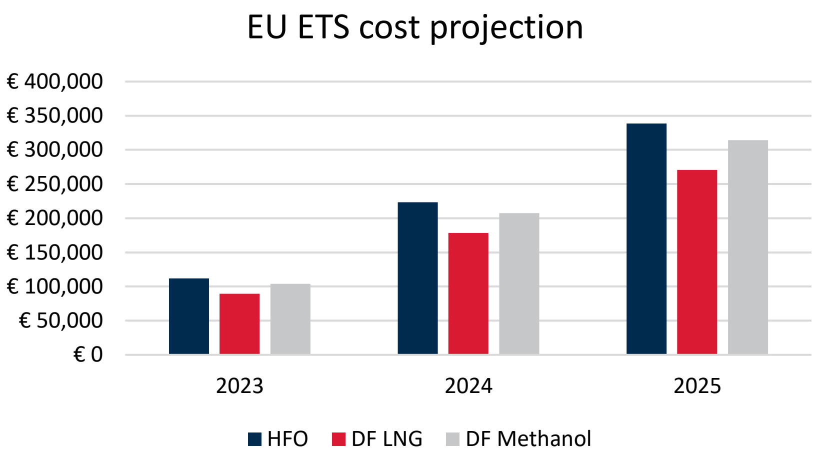


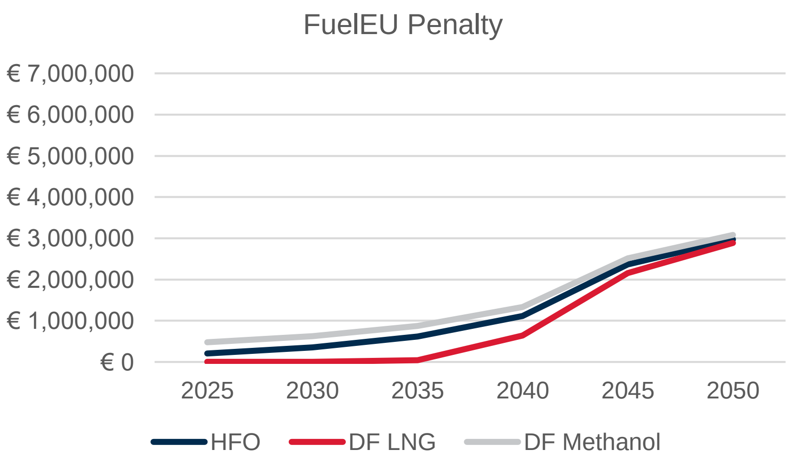
Tanker - VLCC





Containership – 14K TEU



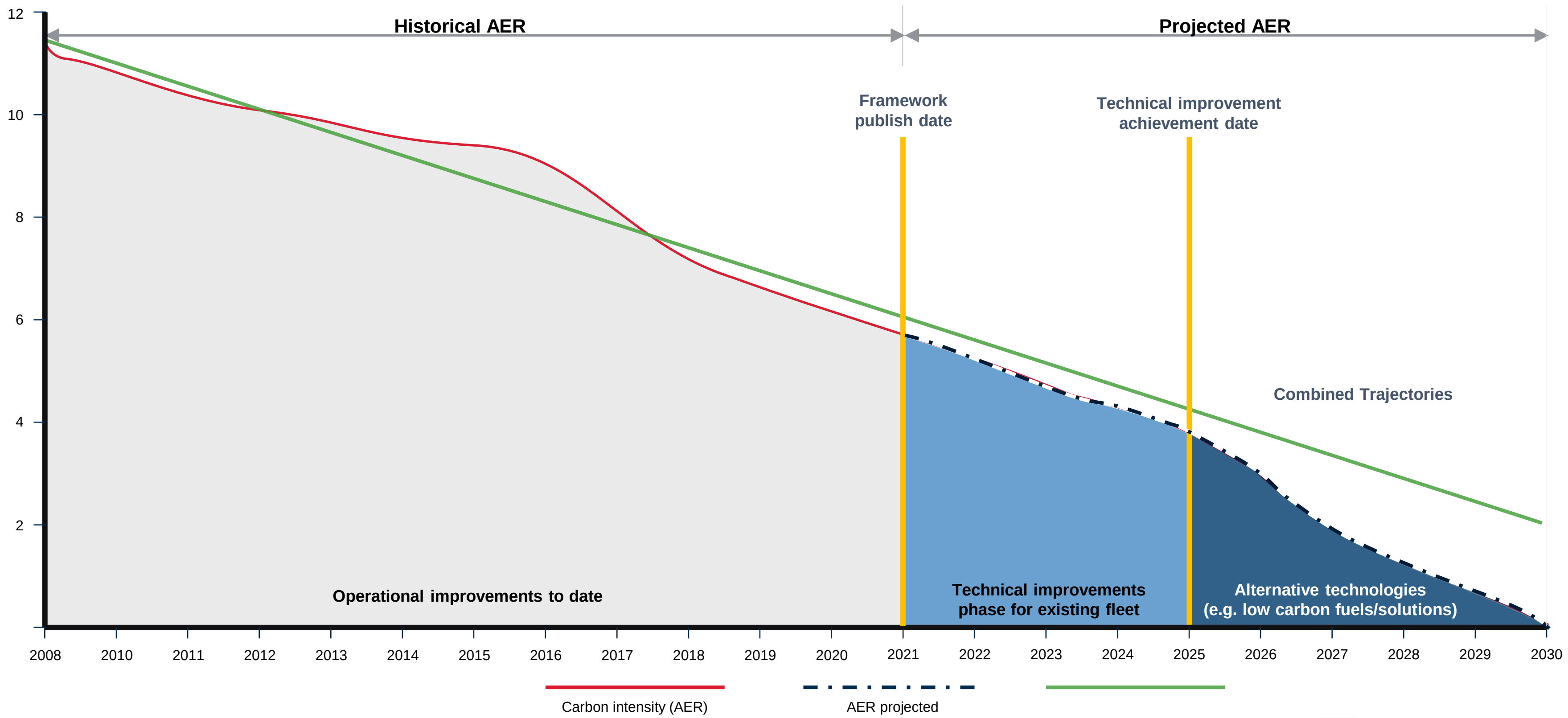


Decarbonization Strategy

Challenge:

- Define pathway for each vessel/fleet to comply with future regulations
- Define regulatory compliance requirements and milestones
- Overlay the impact of Carbon Policies

- 3-step Approach:
    1. **Benchmarking**, GHG and Carbon Intensity calculations
    2. Exploring **Improvement Options** to meet targets,
    3. Monitor KPIs through **Environmental Dashboard**
- Joint Development Projects on technologies and concepts for new builds and existing vessels
    - LNG Carriers, Pure Car and Truck Carriers, Tugs, Container Vessels, Energy Storage Systems
- Launch of simulation-based energy efficiency evaluation services



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Thank You

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